CLAIMS:

1. A method of calculating iteration values for free parameters $\lambda_\alpha^{ortho(n)}$ of a maximum-entropy speech model MESM in a speech recognition system with the aid of the generalized iterative scaling training algorithm in accordance with the following formula:

$$\lambda_\alpha^{ortho(n+1)} = G(\lambda_\alpha^{ortho(n)}, m_\alpha^{ortho}, \ldots)$$

where:

n : is an iteration parameter;

G : is a mathematical function;

α : is an attribute in the MESM; and

m_α^{ortho} : is a desired orthogonalized boundary value in the MESM for the attribute α,

characterized in that the desired orthogonalized boundary value m_α^{ortho} is calculated by linearly combining the desired boundary value m_α with desired boundary values m_β of attributes β that have a larger range than the attribute α.

2. A method as claimed in claim 1, characterized in that the calculation of the desired orthogonalized boundary value m_α^{ortho} for the attribute $\alpha=\beta 0$ comprises the following steps:

a) Selecting all the attributes βi with i=1...g in the speech model that have a larger range RW than the attribute $\alpha=\beta 0$ and include the latter;

b) Calculating desired boundary values $m\beta i$ for the attributes βi with i=0...g;

c) Sorting the attributes βi with i= 0...g according to their RW;

d) Selecting one of the attributes βi having the largest RW;

e) Checking whether there are other attributes βk which include the attribute βi and have a larger RW than the selected attribute βi;

f1) If so, defining a parameter X as a linear combination of the orthogonalized boundary values $m_{\beta k}^{ortho}$ calculated in step g) during the last run of the steps e) to g) for all the attributes βk that have a larger range and are determined in the most recently run step e);

f2) If not, defining the parameters X to X = 0;

g) Calculating the desired orthogonalized boundary value $m_{\beta i}^{ortho}$ for the attribute βi by arithmetically combining the desired boundary value mβi with a parameter X; and

h) Repeating the steps e) to g) for the attribute βi-1 whose RW is smaller than or equal to the RW of the attribute βi until the desired orthogonalized boundary value $m_{\beta 0}^{ortho} = m_{\alpha}^{ortho}$ with i=0 has been calculated in step g).

3. A method as claimed in claim 2, characterized in that the calculation of the parameter X in step f1) is made according to the following formula:

$$X = \sum_k m_{\beta k}^{ortho}$$

4. A method as claimed in claim 3, characterized in that the calculation of the desired orthogonalized boundary value $m_{\beta i}^{ortho}$ is made in step g) according to the following formula:

$$m_{\beta i}^{ortho} = m_{\beta i} - X.$$

5. A method as claimed in claim 2, characterized in that the calculation of the desired boundary values $m_{\beta i}$ for the attributes βi with i= 0,...,g is made in step b) by respectively calculating the frequency N(βi), with which the attribute βi occurs in a training corpus and by subsequently smoothing the calculated frequency value N(βi).

6. A method as claimed in claim 5, characterized in that the calculation of the frequency N(βi) is made by applying a binary attribute function fβi to the training corpus where fβi is defined as:

$$f_{\beta i}(h,w)\ f_{\beta i}(h,w) = \begin{cases} 1 \text{ if } \beta_i \text{ fits in the word sequence (h, w)} \\ \text{otherwise } 0 \end{cases}$$

and where $f_{\beta i}(h,w)$ indicates whether the attribute βi correctly describes a pattern predefined by the word sequence (h,w).

7. A method as claimed in claim 1, characterized in that the mathematical function G has as a further variable the magnitude of a convergence step t_α^{ortho} with:

$$t_\alpha^{ortho} = 1/M^{ortho}$$

where

Mortho: represents for binary functions f_α^{ortho} the maximum number of functions which yield the value 1 for the same argument (h,w).

8. A method as claimed in claim 7, characterized in that the attribute function f_α^{ortho} is calculated by linearly combining an attribute function f_α with orthogonalized attribute functions f_β^{ortho} is calculated from attributes β that have a larger range than the attribute α.

9. A method as claimed in claim 8, characterized in that the calculation of the orthogonalized attribute function f_α^{ortho} for the attribute α=β0 comprises the following steps:

a) Selecting all the attributes βi with i=1...g in the speech model that have a larger range RW than the attribute α=β0 and include the latter;

b) Calculating boundary values fβi for the attributes βi with i=0...g;

c) Sorting the attributes βi with i= 0...g according to their RW;

d) Selecting one of the attributes βi having the largest RW;

e) Checking whether there are other attributes βk which include the attribute βi and have a larger RW than the selected attribute βi;

f1) If so, defining a function F as a linear combination of the orthogonalized attribute function $f_{\beta k}^{ortho}$ calculated in step g) during the last run of the steps e) to g) for all the attributes βk that have a larger range determined in the most recently run step e);

f2) If not, defining the function F to F = 0;

g) Calculating the orthogonalized attribute function $f_{\beta k}^{ortho}$ for the attribute βi by arithmetically combining the attribute function fβi with the function F; and

h) Repeating the steps e) to g) for the attribute βi-1 whose range is smaller than or equal to the range of the attribute βi until the orthogonalized attribute function $f_{\beta 0}^{ortho}=f_{\alpha}^{ortho}$ with i=0 has been calculated in step g).

10. A method as claimed in claim 9, characterized in that the calculation of the function F in step f1) is made according to the following formula:

$$F=\sum_{k} f_{\beta k}^{ortho}.$$

11. A method as claimed in claim 9, characterized in that the calculation of the orthogonalized attribute function $f_{\beta i}^{ortho}$ in step g) is made according to the following formula:

$$f_{\beta i}^{ortho}=f_{\beta i}-F.$$

12. A method as claimed in claim 1, characterized in that the mathematical function G has the following form:

$$\lambda_{\alpha}^{ortho(n+1)}=G(\lambda_{\alpha}^{ortho(n)},m_{\alpha}^{ortho},\ldots)$$
$$=\lambda_{\alpha}^{ortho(n)}+t_{\alpha}^{ortho}\cdot\log\left(\frac{[t_{\alpha}^{ortho}\cdot m_{\alpha}^{ortho}+b_{\alpha}]}{[t_{\alpha}^{ortho}\cdot m_{\alpha}^{ortho(n)}+b_{\alpha}]}\cdot\frac{1-\sum_{\gamma}[t_{\gamma}^{ortho}\cdot m_{\gamma}^{ortho(n)}+b_{\gamma}]}{1-\sum_{\gamma}[t_{\gamma}^{ortho}\cdot m_{\gamma}^{ortho}+b_{\gamma}]}\right)$$

where:

α : refers to a just considered attribute;

γ : refers to all the attributes in the speech model;

t_α^{ortho}, t_γ^{ortho} : refer to the size of the convergence step with $t_\alpha^{ortho} = t_\gamma^{ortho} = 1/M^{ortho}$ with

$$M^{ortho} = \max_{(h,w)}\left(\sum_\beta f_\beta^{ortho}(h,w)\right);$$

where Mortho for binary functions f_β^{ortho} represents the maximum number of functions which yield the value 1 for the same argument (h,w);

m_α^{ortho}, m_γ^{ortho} : refers to desired orthogonalized boundary values in the MESM for the attributes α and γ;

$m_\alpha^{ortho(n)}$, $m_\gamma^{ortho(n)}$: refers to iterative approximate values for the desired boundary values m_α^{ortho}, $m_\gamma^{ortho(n)}$; and

bα and bγ : refer to constants.

13. A method as claimed in claim 1, characterized in that the mathematical function has the following form:

$$\lambda_\alpha^{ortho(n+1)} = G(\lambda_\alpha^{ortho(n)}, m_\alpha^{ortho}, \ldots) = \lambda_\alpha^{ortho(n)} + t_\alpha^{ortho} \cdot \log\left(\frac{m_\alpha^{ortho}}{m_\alpha^{ortho(n)}} \cdot \frac{1 - \sum_{\beta \in Ai(n)} (t_\beta \cdot m_\beta^{ortho(n)})}{1 - \sum_{\beta \in Ai(n)} (t_\beta \cdot m_\beta^{ortho})}\right)$$

where:

n : represents the iteration parameter;

Ai(n) : represents an attribute group Ai(n) with 1≤i≤m selected in the n^th iteration step;

α : represents a just considered attribute from the just selected attribute group Ai(n);

β : represents all the attributes of the attribute group Ai(n);

t_α^{ortho}, t_β^{ortho} : represents the size of a convergence step with $t_\alpha^{ortho} = t_\beta^{ortho} = 1/M_{i(n)}^{ortho}$ with

$$M_{i(n)}^{ortho} = \max_{(h,w)}\left(\sum_{\beta \in Ai(n)} f_\beta^{ortho}(h,w)\right)$$

where $M_{i(n)}^{ortho}$ represents for binary functions f_{β}^{ortho} the maximum number of functions from the attribute group Ai(n), which yield the value 1 for the same argument (h,w);

m_{α}^{ortho}, m_{β}^{ortho} : represent desired orthogonalized boundary values in the MESM for the attributes α and β respectively;

$m_{\alpha}^{ortho(n)}$, $m_{\beta}^{ortho(n)}$: represent iterative approximate values for the desired boundary values m_{α}^{ortho}, m_{β}^{ortho};

where the selection of the group Ai(n) of attributes α, whose associated parameters λ_{α}^{ortho} are adapted to a current iteration step is made either cyclically or according to a predefined criterion.

14. A speech recognition system (10) comprising: a recognition device (12) for recognizing the semantic content of an acoustic signal captured and rendered available by a microphone (20), more particularly a speech signal, by mapping parts of this signal onto predefined recognition symbols as they are offered by the implemented maximum-entropy speech model MESM, and for generating output signals which represent the recognized semantic content; and a training system (14) for adapting the MESM to recurrent statistical patterns in the speech of a certain user of the speech recognition system (10); characterized in that the training system (14) calculates free parameters λ in the MESM in accordance with the method as claimed in claim 1.

15. A training system (14) for adapting the maximum-entropy speech model MESM in a speech recognition system (10) to recurrent statistical patterns in the speech of a certain user of this speech recognition system (10), characterized in that the training system (14) calculates free parameters λ in the MESM in accordance with the method as claimed in claim 1.